# Global Non-Hydrostatic Modelling
# – A Brief Synopsis of Important Results and Outstanding Questions

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**Courtesy of the DYAMOND team**

2nd DYAMOND-ESiWACE Hackathon
Wednesday, 19 June 2019 – Friday, 21 June 2019
Atrium Hotel, Flugplatzstr. 44, 55126 Mainz, Germany
Talk: Wednesday, 19 June, 9:15-9:45
**https://www.esiwace.eu/events/19-21-june-2019-dyamond-2nd-hackathon-mainz-de**

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The first inter-model-comparison project of global atmospheric circulations models with storm-resolving grid scales (1 km to 5 km)

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# The DYAMOND Inititative

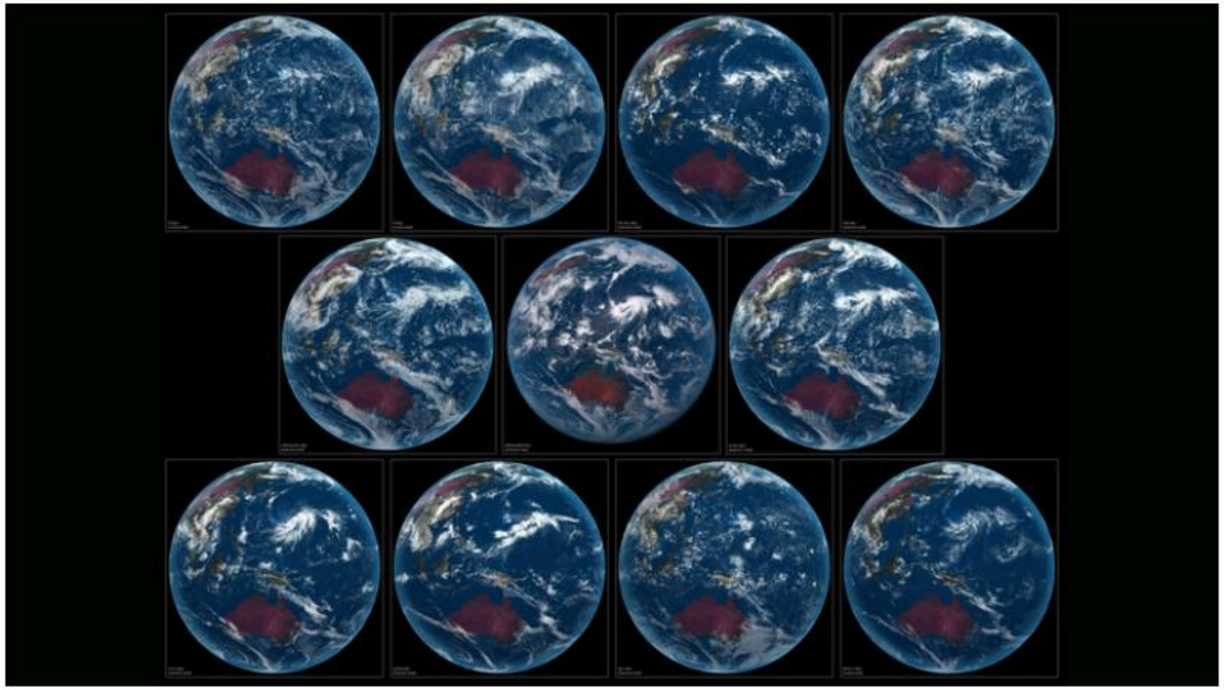

Figure: Simulation examples of the DYAMOND initiative (simulated day Aug 4th 2016). Can you tell which one is observation? By clicking on the image you can get a larger version (attention 20 MB)

**DYAMOND** stands for **DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains.** This initiative project describes a

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**UPCOMING EVENTS**

ISC 2019

Jun 16, 2019 - Jun 20, 2019 — Frankfurt (DE)

5th OpenIFS User Workshop: The Impact of moist processes on weather forecasts

Jun 17, 2019 - Jun 21, 2019 — Reading (UK)

2nd DYAMOND-ESiWACE Hackathon

Jun 19, 2019 - Jun 21, 2019 — Mainz (DE)

Previous events…

Upcoming events…

**NEWS**

How #ESiWACE and #ESiWACE2 contribute to the #WMO?

Mar 23, 2019

# References on DYAMOND


- Stevens, B., Satoh, M., Auger, L., Biercamp, J., Bretherton, C., Chen, X., Duben, P., Judt, F., Khairoutdinov, M., Klocke, D., Kodama, C., Kornblueh, L., Lin, S.-L., Putman, W., Shibuya, R., Neumann, P., Rober, N., Vannier, B., Vidale, P.-L., Wedi, N., Zhou, L. (2019) DYAMOND: The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains. Progress in Earth and Planetary Science, in review.
- Satoh, M., Stevens, B., Judt, F., Khairoutdinov, M., Lin, S., Putman, W.M., Düben, P. (2019) Global Cloud-Resolving Models. Current Climate Change Reports, doi:10.1007/s40641-019-00131-0.
- Special Edition on "DYAMOND: The DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains" in Journal of the Meteorological Society of Japan (JMSJ)

  https://jmsj.metsoc.jp/CallForPaper_2019JMSJ_DYAMOND.pdf

# Top ten reasons why GCRM is a great leap

1. Represents the mesoscale (2 to 2000 km) and its link to the general circulation MCSs
2. Represents the multiscale physics and scale interactions inherent in atmospheric moist convection MJO
3. Represents the dynamic and thermodynamic drivers of cloud microphysical processes cloud microphysics
4. Represents the mean state to which small scale turbulence responds and captures gravity, and inertial-gravity waves, and thereby main mechanisms of wave mean flow interaction GW
5. Simulates the same quantities that the satellites observe, enabling the critical application of these observations satellite
6. Provides an additional source of empiricism using "nature runs" with hector or kilometer-scale simulations on short time periods NR
7. Opens the possibility of global cloud-resolving earth system models by enabling important coupling pathways to the ocean AO-coupling
8. Allows for one model and avoids the need for (and challenges of) downscaling thereby providing a direct link to application and impact communities GCM-RCM
9. Represents main constituent transport mechanisms, thus linking observed concentrations of important trace species to their sources and sinks transports
10. Advances information science, by spurring developments in both hardware and software, e.g., to deal with data flows, or hierarchical computational architecture HPC

After Bjorn Stevens talk at EGU2018

Satoh et al. (2019) Global Cloud-Resolving Models. *Current Climate Change Reports*, doi:10.1007/s40641-019-00131-0

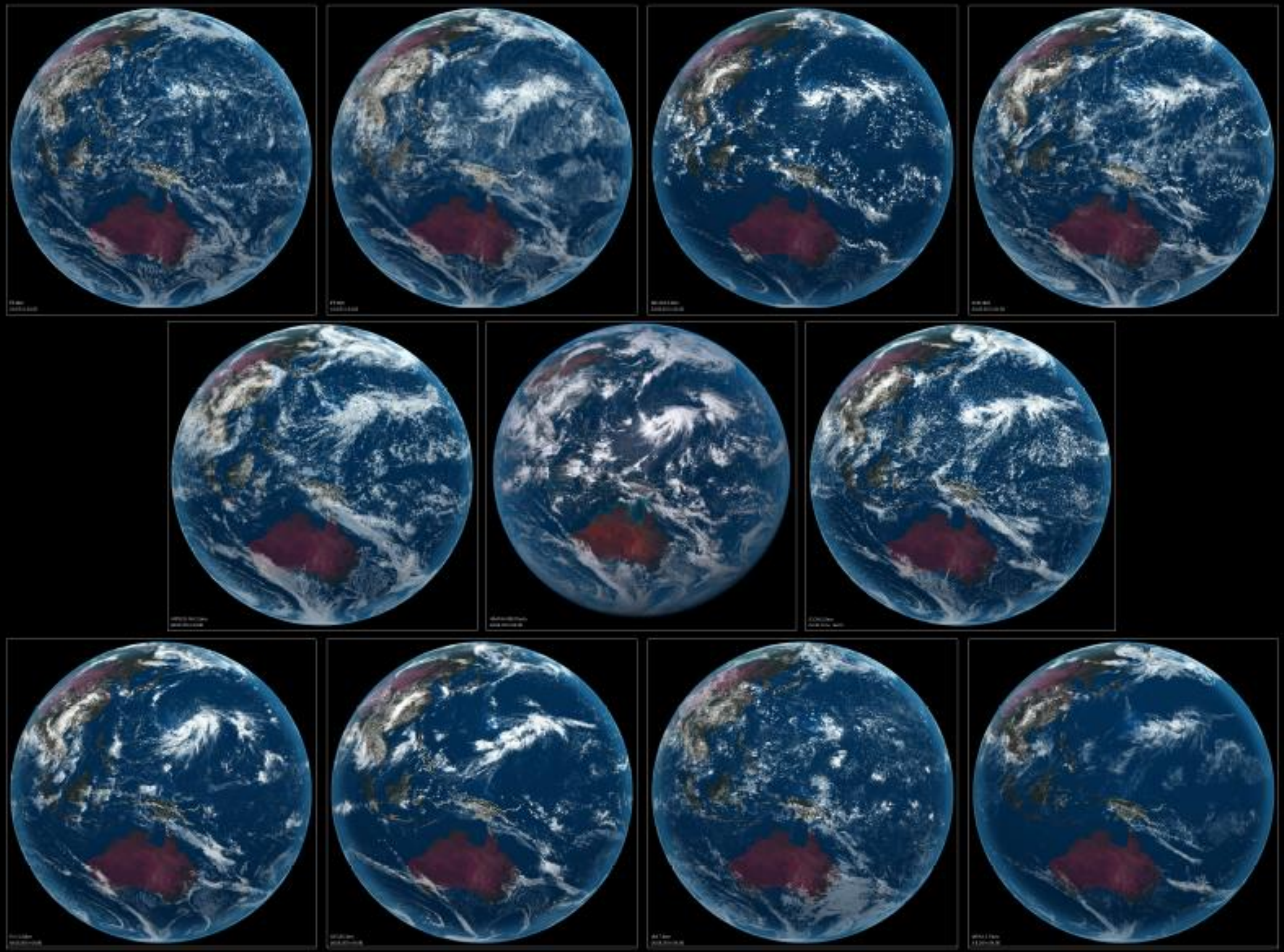
| Name | Grid | $\#_{\text{Mcol}}$ | $\#_{\text{lev}}$ | $\#_{\mu}$ | $\sqrt{A_{\text{max}}}$ | Top | Sponge | CP | BL | FC |
|---|---|---|---|---|---|---|---|---|---|---|
| ARPEGE-NH | Kurihara | 82 | 75 | 5 | 2.5 km | 70 km | 34 km | N | T | yes |
| FV3 | Cube | 57 | 79 | 6 | 3.3 km | 39 km | 25 km | S | K | yes |
| GEOS | Cube | 57 | 132 | 5 | 3.3 km | 80 km | 75 km | F | K | yes |
| ICON | Icoso | 84 | 90 | 5 | 2.5 km | 75 km | 44 km | N | T | yes |
| IFS | Octo | 26 | 137 | 5 | 4.8 km | 80 km | 65 km | S | K | yes |
| MPAS | Voronoi | 42 | 75 | 5 | 3.8 km | 40 km | 30 km | F | T | yes |
| NICAM | Icoso | 42 | 78 | 5 | 3.5 km | 50 km | 25 km | N | K | no |
| SAM | La-Lo | 43 | 74 | 5 | 4.3 km | 37 km | 22 km | N | S | no |
| UM | La-Lo | 20 | 85 | 6 | 7.8 km | 85 km | 42 km | S | K | yes |

| Model | Contact Person |
|---|---|
| ICON | Luis Kornblueh |
| NICAM | Ryosuke Shibuya<br>Chihiro Kodama |
| MPAS | Falko Judt |
| NASA GEOS5 | William Putman |
| FV3 | Shiann-Jiann Linn |
| SAM | Marat Khairoutdinov |
| UM | Pier Luigi Vidale |
| ARPEGE-NH | Ludovic Auger |
| IFS-H | Peter Dueben, Nils Wedi |

Configuration of the DYAMOND models.
Tabulated are the number of columns (in millions), vertical levels, (not counting soil levels), and microphysical variables, the linear dimension of the area, A of the largest tile, the vertical span of the column and the height where the sponge layer begins.

The last three columns denote parameterization assumptions:
For cumulus parmaterization (denoted CP) the letters `N',`S', and `F' denoting none, shallow or full parameterization, whereby for the latter some assumptions are usually included in an attempt to account for the scale of motions being parameterized.
For the boundary layer parameterization (denoted BL) the letters `T', `K' and `S’ denote either a TKE-like model (including an additional prognostic equation), a diagnostic eddy-diffusivity, or a Smagorinsky-like three-dimensional closure as is common for large-eddy simulation.
Finally some indication is given as to whether fractional cloudiness (denoted FC) is Parameterized.

# Some impressions from DYAMOND

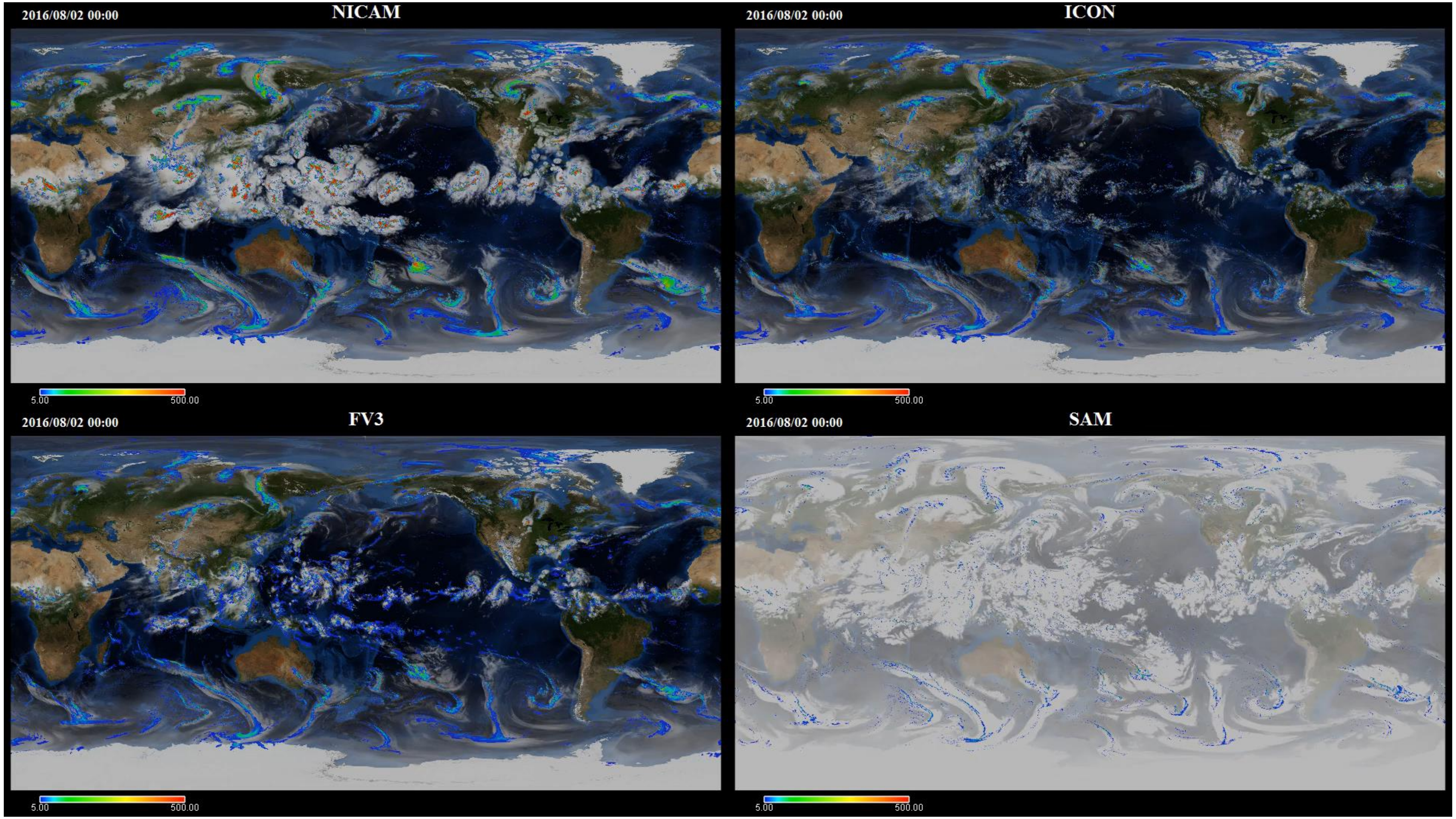


Stevens et al. (2019, PEPS)

# Overview for August 1st to September 10th using NICAM, ICON, FV3 and SAM — OLR and precipitation

NICAM

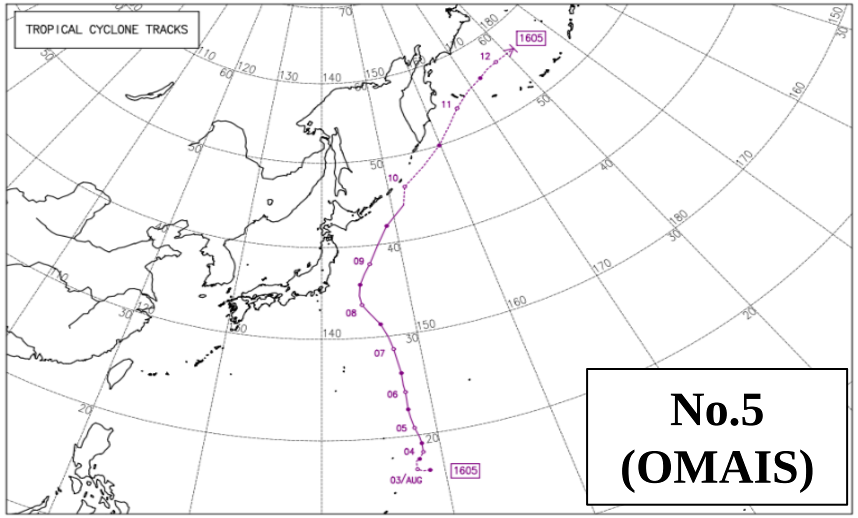
ICON



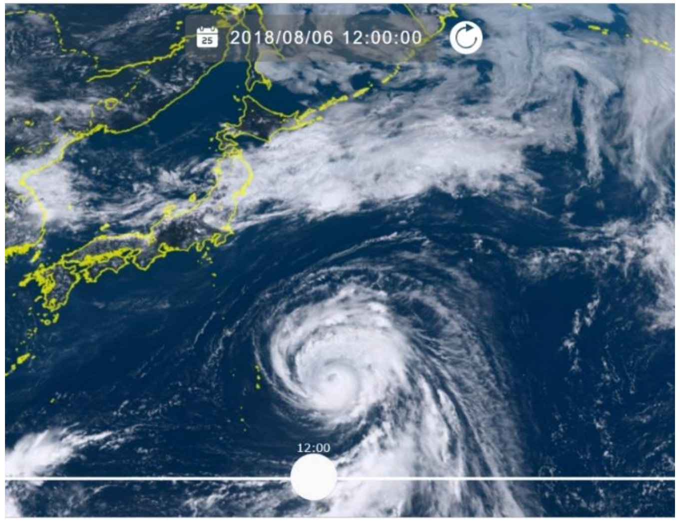

FV3

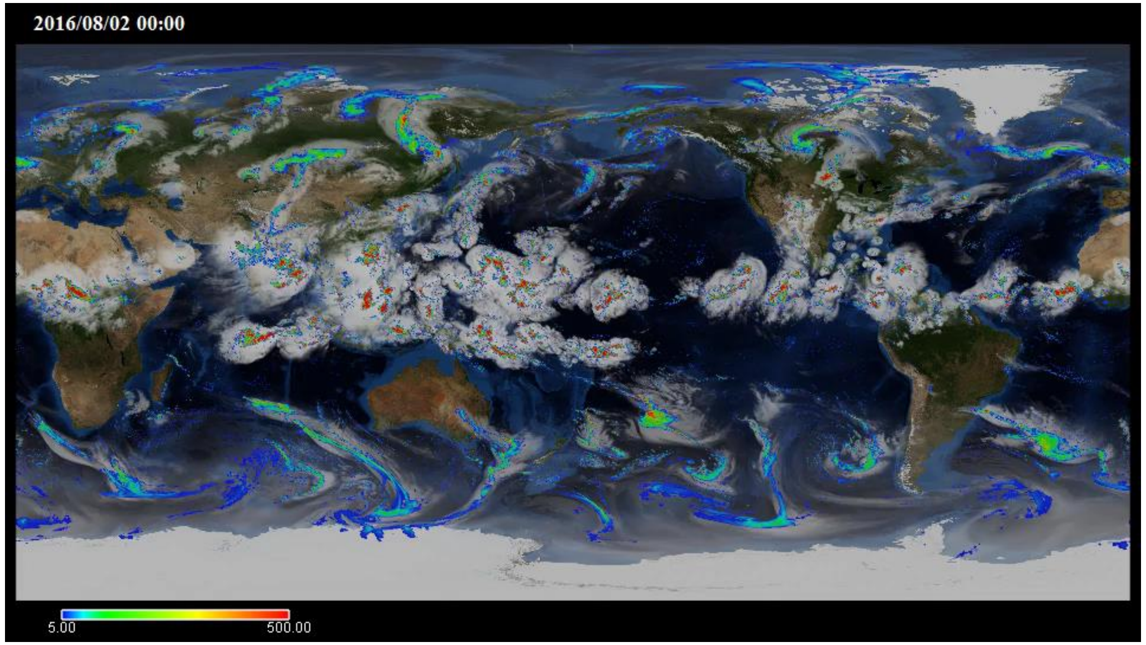
SAM

# A tropical cyclone “OMAIS” was generated at August 3rd at the south of Japan

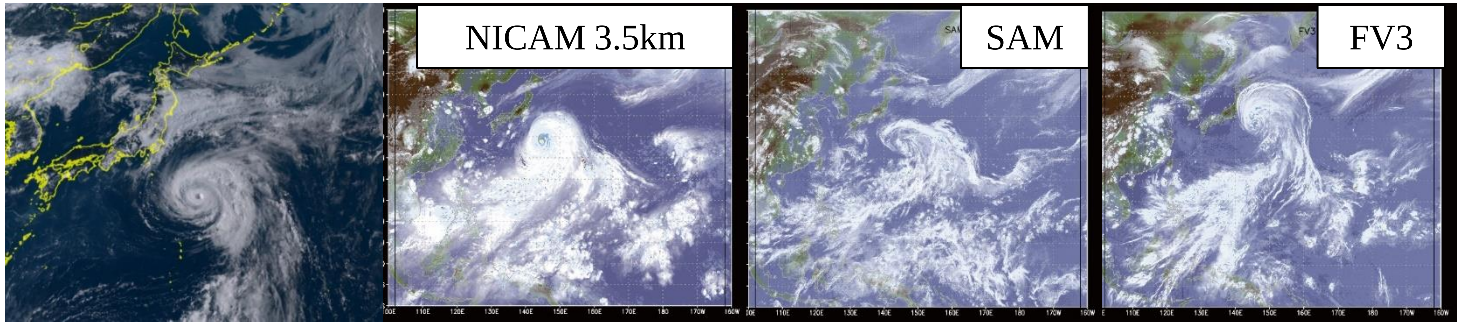



Obs. Himawari-8, Aug 6, 2016

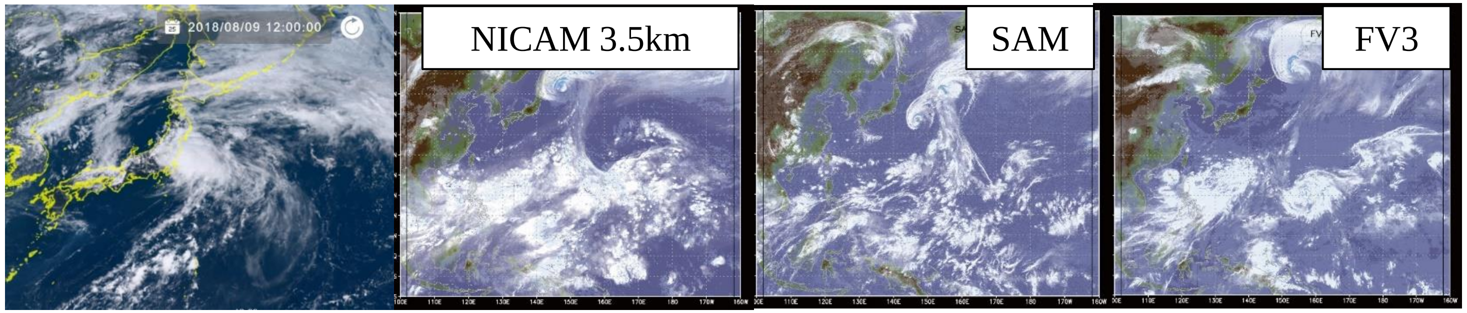


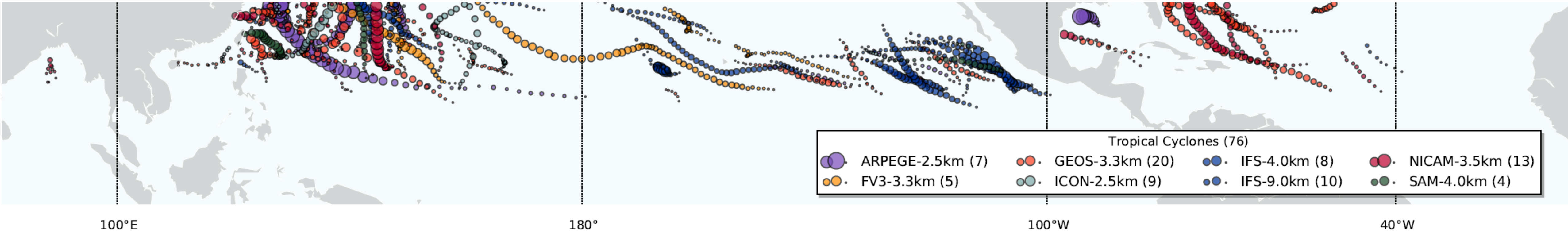
# 2016/08/07 6:00 UTC; A snapshot for Tropical cyclone OMAIS




2016/08/09 3:00 UTC

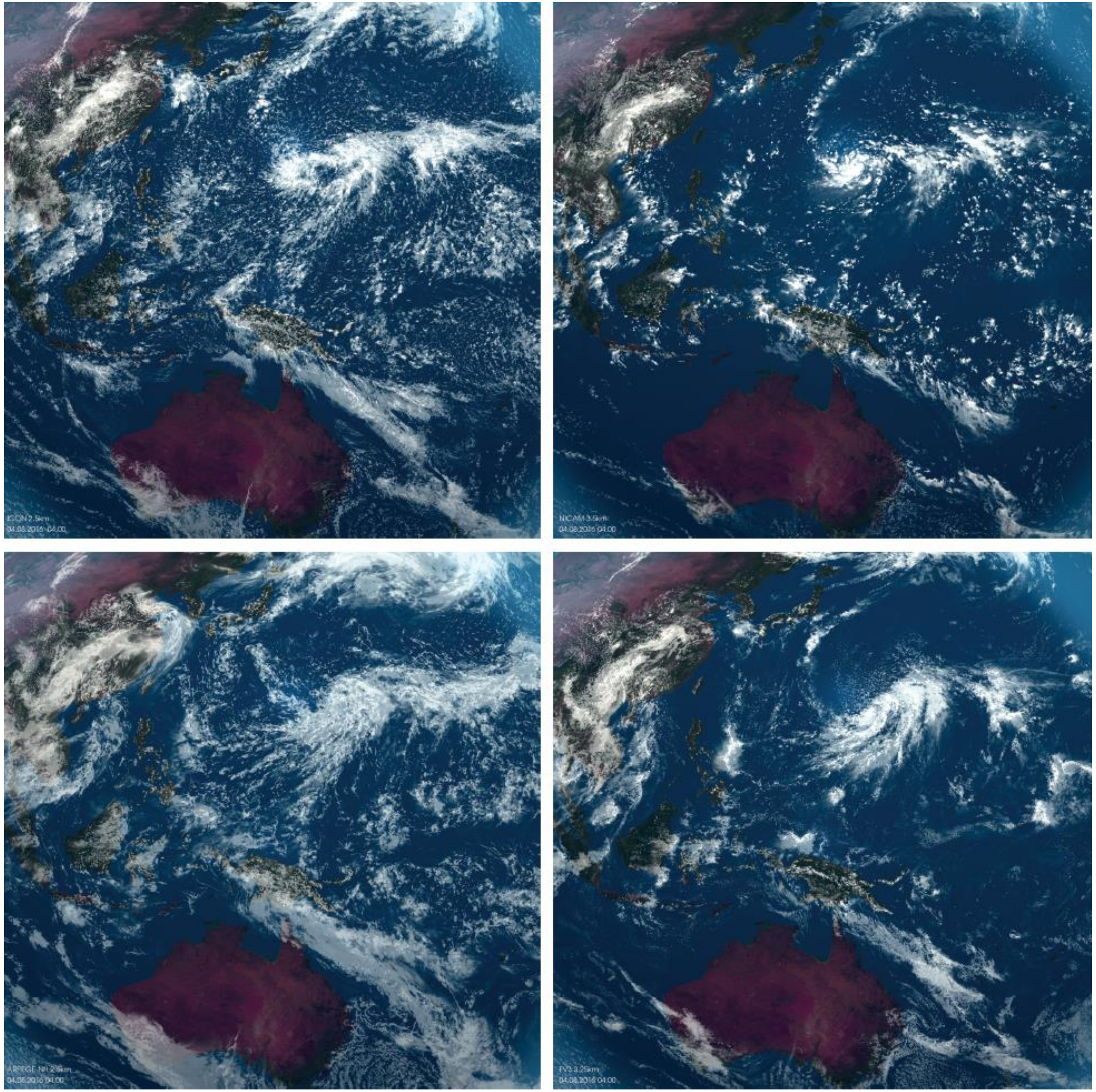



- Each model successfully simulates the tropical cyclone OMAIS as a hindcast
- The northward migration of OMAIS simulated by NICAM and FV3 is slightly faster, while OMAIS by SAM disappears at east of Japan without the northward migration
- The comparison of the structure of OMAIS should be interesting (future work)



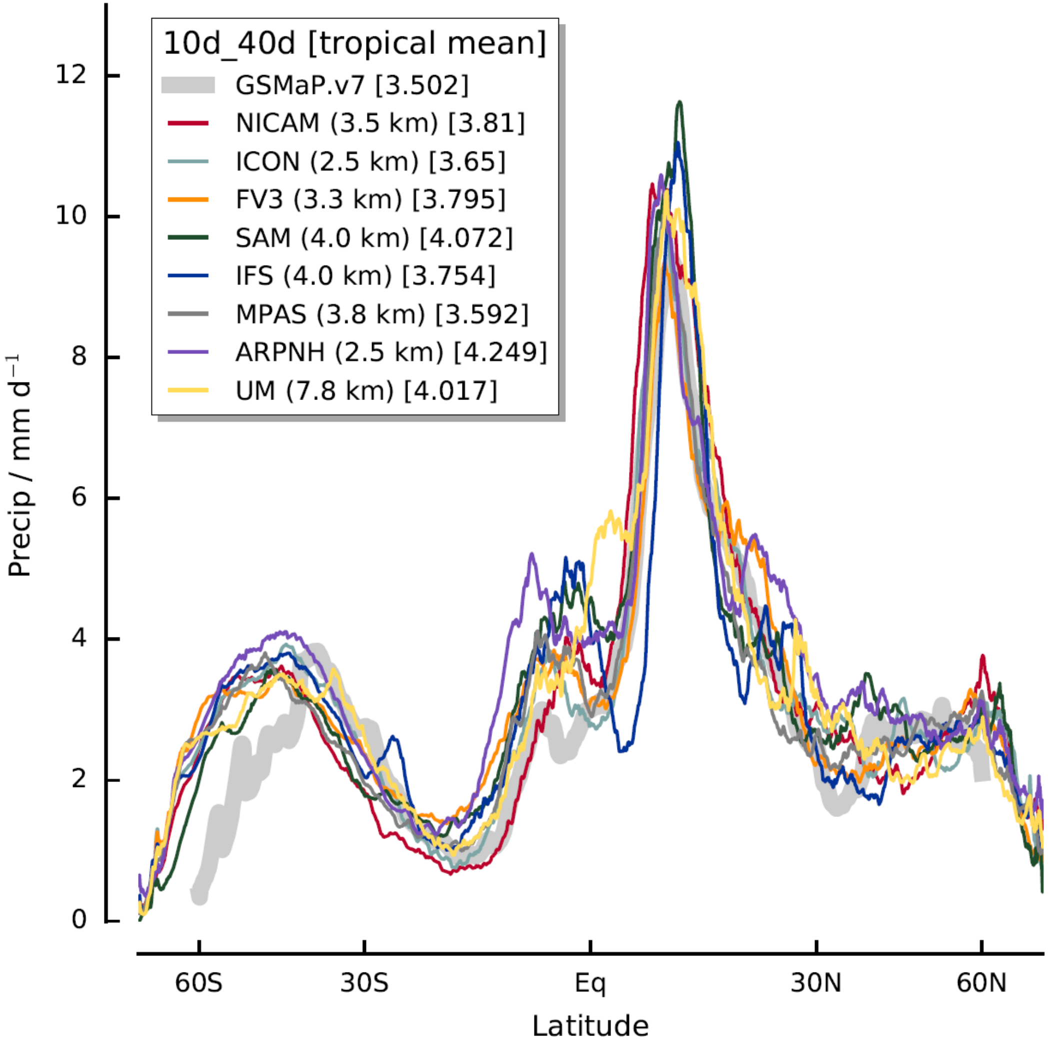

Tropical cyclone tracks. Tracks of tropical cyclones identified from a subset of the available DYAMOND models following procedures outlined in the text. Total number of tropical cyclones identified given in parentheses.

Stevens et al. (2019, PEPS)




Structure of tropical cloud fields in the vicinity of Omais.

Stevens et al. (2019, PEPS)

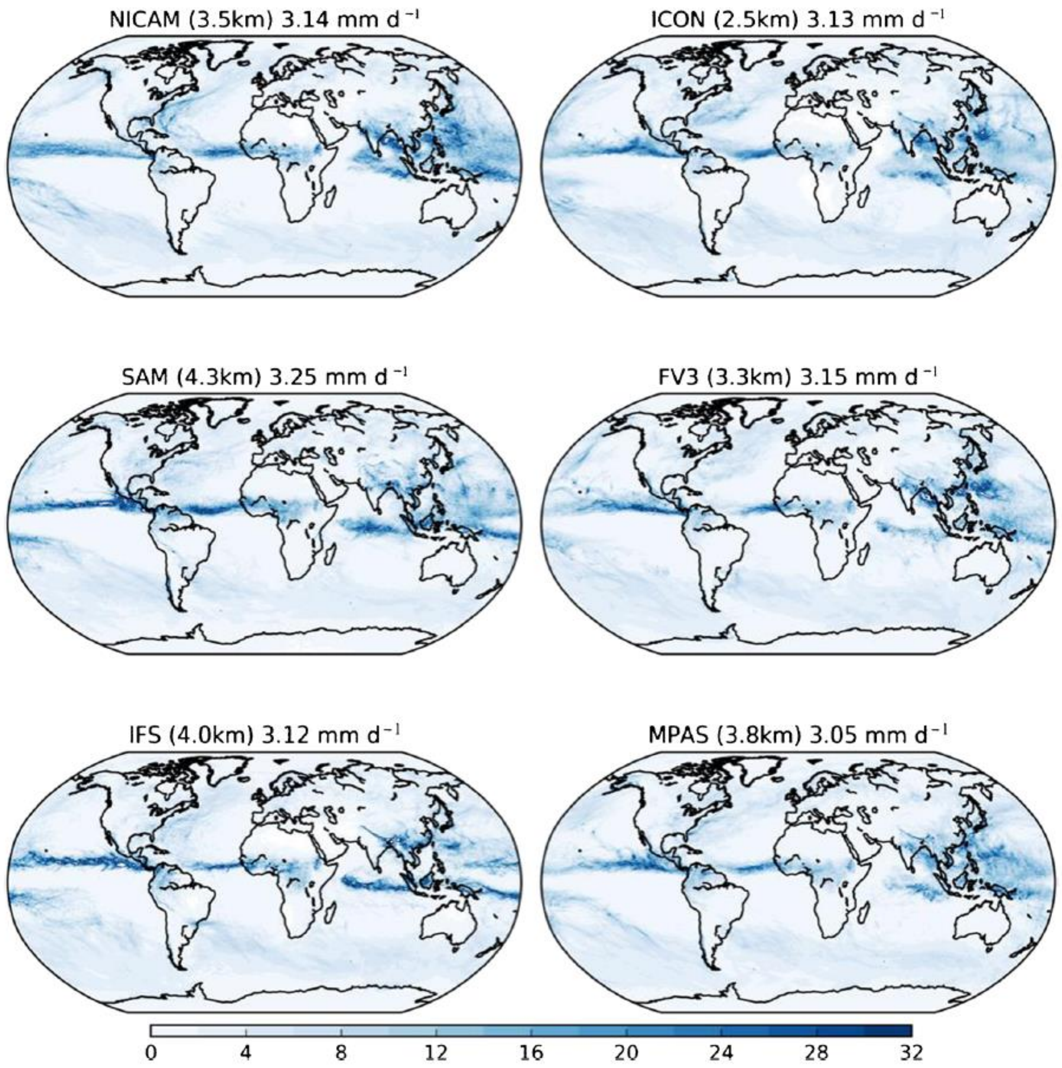



**Mean precipitation. Precipitation is zonally and temporally averaged (over the last thirty days of the simulation) for each of the indicated models.**

- The global averaged precipitation for each model is indicated in the legend.
- Mean precipitation from the GSMaP project (version 7) is provided as a reference. The GSMaP line width is to distinguish it from the models, not a measure of retrieval

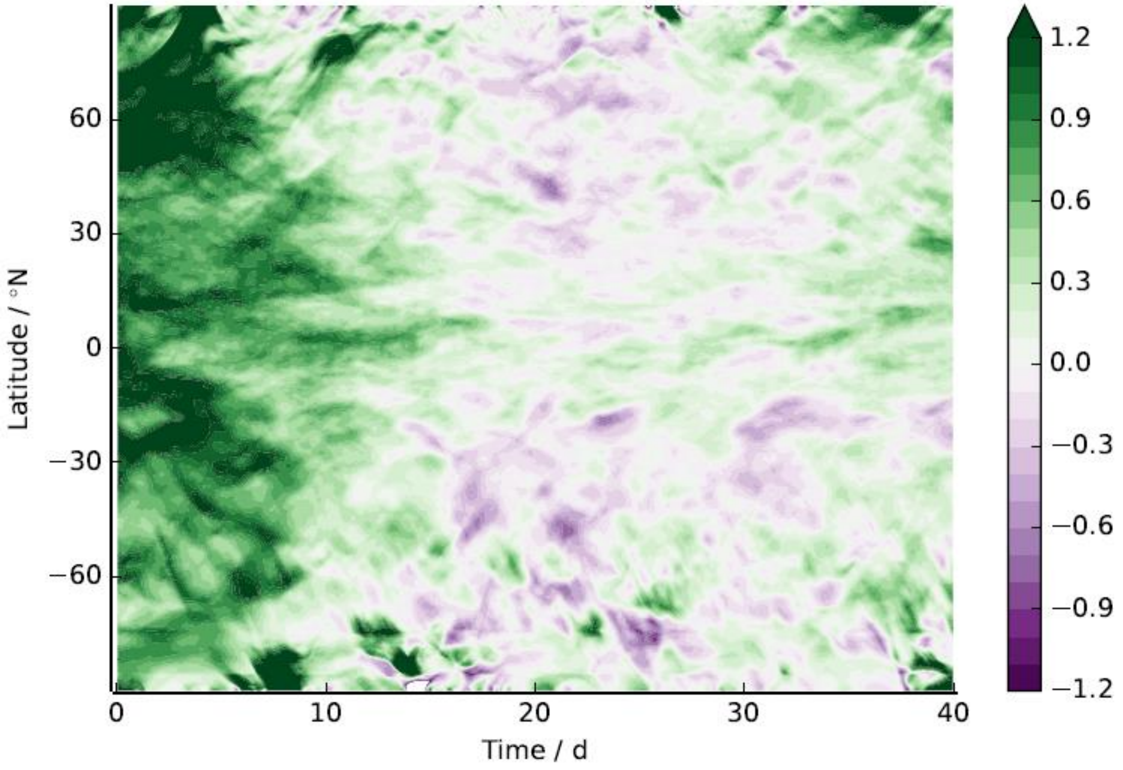
Stevens et al. (2019, PEPS)

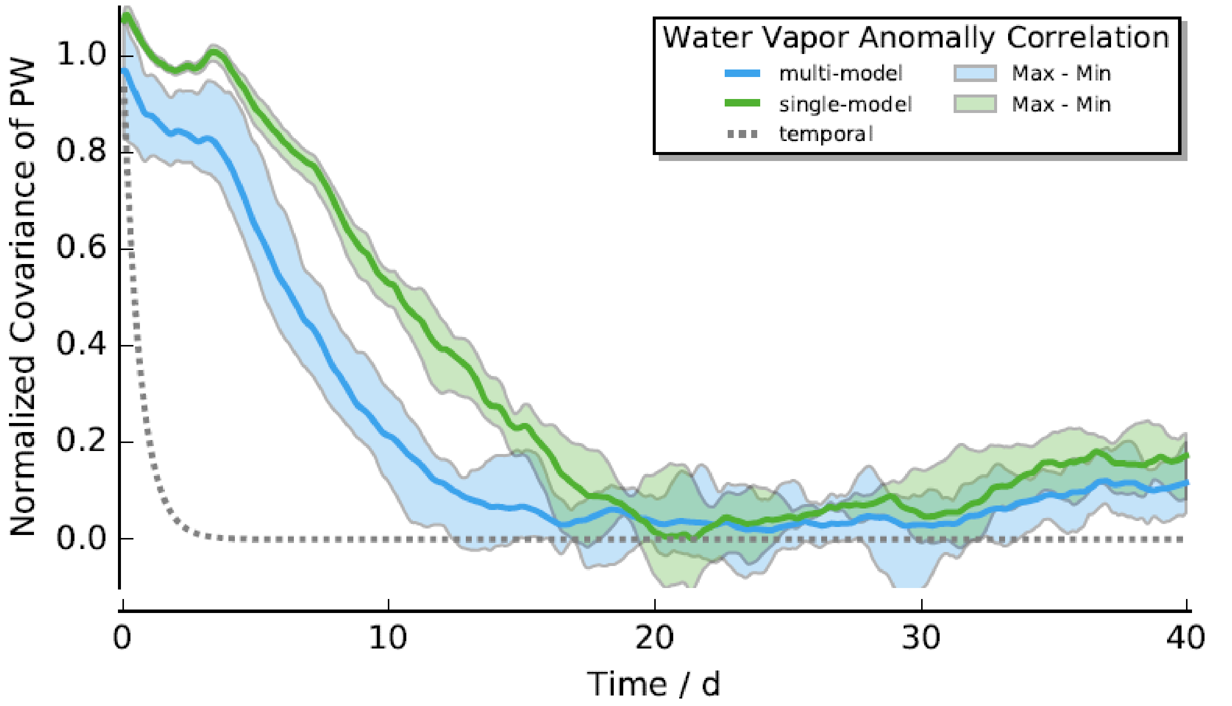
# 30-day averaged total precipitation




Global distribution of the average precipitation simulated by six GCRMs for the DYAMOND project between August 10 and September 10, 2016.
Numbers just above each figure are averaged precipitation over the sphere.

Satoh et al. (2019,CCCR)



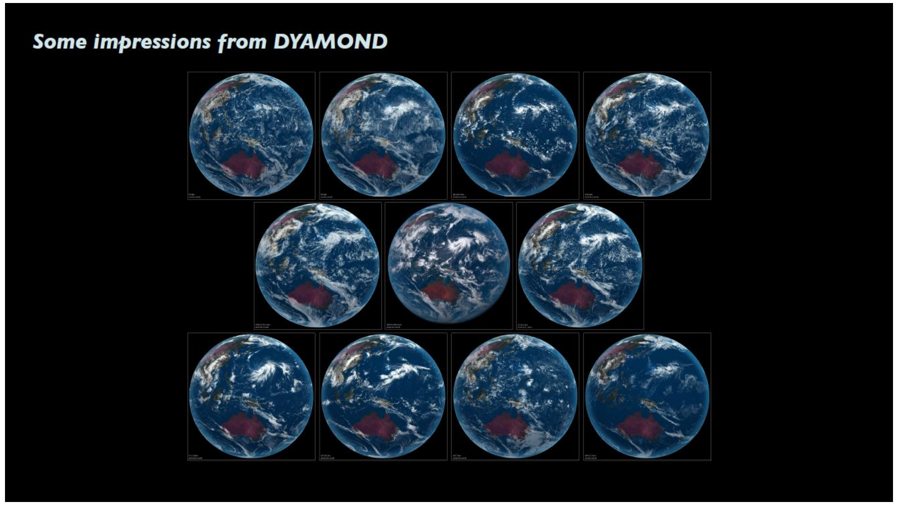

Water vapor anomaly correlation. Zonally averaged anomaly correlation of hourly (0:1) precipitable water between ICON-2.5km and GEOS-3.3km normalized by zonally and temporally averaged water-vapor variance from ICON-2.5km plotted as a function of time and latitude.

Temporal decrease of globally averaged water vapor anomaly correlation. The intermodel decay is for the three ICON-2.5km and two versions of the ICON-5.0km model, intramodel decay is from 11 pairs of models.

Predictability estimation by Mapes et al. (2008,JMSJ)

Stevens et al. (2019, PEPS)

# Highlighed results of DYAMOND and beyond




- To be analyzed
  - Meso-scale statistics
  - Resolved transports:
    momentum/energy/water
  - Gravity waves
  - Cloud characteristics
    and their relations to circulations

- DYAMOND
  - The DYAMOND experiment has been successfully finished (Stevens et al., 2019, PEPS, submitted).
  - The tropical cyclone OMAIS is successfully simulated by all the models.
  - BSISO predictability for 3-4 weeks. All the models have worse prediction skill in their higher resolutions
  - Zonal mean precipitation very comparable to observation (GSMaP), why?
  - More biases of OLR and precipitation for higher resolutions
- DYAMOND2 (TBD)
  - atmosphere-ocean coupled mode
  - +4K exp.
  - ensemble experiments: initial condition or physics sensitivities
  - EUREC$^4$A case; Jan.-Feb. 2020